Characteristics influencing outcomes of corneal collagen crosslinking for keratoconus and ectasia: Implications for patient selection

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PURPOSE: To determine preoperative patient characteristics that may predict topography and visual acuity outcomes of corneal collagen crosslinking (CXL).

SETTING: Cornea and refractive surgery practice.

DESIGN: Cohort study.

METHODS: Crosslinking was performed in eyes with keratoconus or corneal ectasia. Multiple regression and odds ratio analyses were performed to determine independent predictors of changes in topography-derived maximum keratometry (K) and corrected distance visual acuity (CDVA) 1 year postoperatively. Preoperative characteristics included sex, age, uncorrected distance visual acuity (UDVA), CDVA, maximum keratometry (K), corneal thickness, corneal haze, disease group, and cone location. Postoperative improvement in maximum K was defined as flattening of 2.0 diopters (D) or more and worsening as steepening of 1.0 D or more. Improvement in CDVA was defined as a gain of 2 lines or more and worsening as a loss of 1 line or more.

RESULTS: The study comprised 104 eyes (66 keratoconus; 38 corneal ectasia). Eyes with a preoperative CDVA of 20/40 or worse were 5.9 times (95% confidence interval [CI], 2.2-6.4) more likely to improve 2 Snellen lines or more. Eyes with a maximum K of 55.0 D or more were 5.4 times (95% CI, 2.1-14.0) more likely to have topographic flattening of 2.0 D or more. No preoperative characteristics significantly predicted worsening of visual acuity or corneal topography.

CONCLUSIONS: Patients with worse preoperative CDVA and higher K values, particularly with a CDVA of 20/40 or worse or a maximum K of 55.0 D or more, were most likely to have improvement after CXL. No preoperative characteristics were predictive of CXL failure.

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Corneal collagen crosslinking (CXL) is a treatment for keratoconus and corneal ectasia, the principle goal of which is to stabilize the progression of these corneal diseases.[1] Previous studies[2–9] report that in addition to stabilizing the cornea, there is, on average, improvement in topographic and visual acuity outcomes. For example, in our previous report of 1-year CXL outcomes,[10] the topography-derived maximum keratometry (K) value flattened by 1.7 diopters (D) and patients had an improvement in corrected distance visual acuity (CDVA) from 20/45 to 20/34 and in uncorrected distanced visual acuity (UDVA) from 20/137 to 20/117. Moreover, there was a general improvement in several corneal topography indices, corneal and total eye higher-order aberrations, and subjective patient visual symptoms.[10–12]

In addition to such average population statistics, in a clinical setting it is important to identify predictors of positive and negative CXL outcomes to aid the ophthalmologist in choosing appropriate candidates for CXL and to guide the patient's proper expectations. Are there preoperative characteristics that might predict patients in whom CXL would not stabilize the disease process or would lead to loss of vision or patients who would be more likely to achieve actual improvement in topography and visual function? In this study, we analyzed the preoperative characteristics that may influence changes in corneal topography

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and visual acuity after CXL to begin to determine patients who are best treated with CXL and those who are poor candidates.

PATIENTS AND METHODS

Patients with progressive keratoconus or ectasia after laser in situ keratomileusis (LASIK) or photorefractive keratectomy (PRK) were enrolled as part of a multicenter prospective randomized controlled clinical trial.[A,B] This study was approved and monitored by an investigational review board, was U.S. Health Insurance Portability and Accountability Act compliant, and adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all patients.

The inclusion criteria included 14 years of age or older and axial topography consistent with keratoconus or corneal ectasia. Progressive keratoconus or ectasia was defined as 1 or more of the following changes over a period of 24 months: an increase of 1.0 D or more in the steepest keratometry (K), an increase of 1.0 D or more in the manifest cylinder, or an increase of 0.5 D or more in the manifest refraction spherical equivalent. Exclusion criteria included a history of corneal surgery (except previous LASIK or PRK), chemical injury, delayed epithelial healing, and a corneal thickness less than 300 µm.

Surgical Technique

Crosslinking was performed according to the methodology described by Wollensak et al.[1] Topical anesthesia was administered, and the corneal epithelium was removed by mechanical debridement over the central 9.0 mm. Riboflavin (0.1% in 20.0% dextran T500 solution, Medio Cross, Peschke Meditrade GmbH) was then administered topically every 2 minutes for a total of 30 minutes. After riboflavin administration, riboflavin absorption throughout the corneal stroma and anterior chamber was confirmed on slitlamp examination. Ultrasonic pachymetry was performed; if the cornea was less than 400 µm, hypotonic riboflavin (0.1% in sterile water, Medio Cross hypotonic) was administered, 1 drop every 10 seconds for 2-minute sessions, after which ultrasonic pachymetry was performed to confirm that the stroma had swollen to more than 400 µm. This was repeated until adequate corneal thickness was obtained.

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The cornea was exposed to ultraviolet-A (UVA) 365 nm light (UV-X system, IROC Innocross AG) for 30 minutes at an irradiance of 3.0 mW/cm^2. During UVA exposure, riboflavin drops were continued every 2 minutes.

Postoperatively, antibiotic and corticosteroid drops were administered and a therapeutic soft contact lens (Acuvue Oasys, Vistakon Pharmaceuticals, LLC) was placed. The contact lens was removed after epithelial healing, typically 3 to 5 days postoperatively. Antibiotic drops were continued for 1 week, and corticosteroid drops were continued for 2 weeks.

Clinical Measurements

Visual Acuity The CDVA was measured preoperatively and 1 year postoperatively. High-contrast visual acuity measurements were obtained under controlled lighting conditions using a modified Lighthouse Early Treatment Diabetic Retinopathy Study visual acuity test (2nd edition) with Sloan letters. Patients were tested 4 m from the visual acuity chart. If patients could not read any letters at 4 m, they were tested at 2 m.

Maximum Keratometry and Topographic Cone Location Topography measurements were obtained using a Scheimpflug-based corneal topography instrument (Pentacam, Oculus Optikgeräte GmbH). Maximum K data were obtained preoperatively and 1 year postoperatively.

A previous study[13] found that the magnitude of postoperative flattening after CXL was associated with preoperative cone location. Therefore, cone location was assessed as a preoperative characteristic in this study. The detailed methodology has been described.[13] In brief, the preoperative cone location, defined by the Scheimpflug coordinates of maximum K, were divided into 2 groups as follows: eyes in which the maximum K was located in the central 3.0 mm optical zone (central cone) and eyes in which the maximum K was located outside the central 3.0 mm optical zone (peripheral cone).

Corneal Thickness (Pachymetry) Measurements Pachymetry measurements were obtained using the Scheimpflug instrument. The thinnest point on the corneal thickness map was obtained preoperatively and 1 year postoperatively.

Corneal Haze Measurements A complete description of the method used for measuring corneal haze using Scheimpflug densitometry has been described in detail.[14] Briefly, images of all eyes were taken with the Scheimpflug instrument before the procedure and 1 year postoperatively. Using perimetry software included with the instrument, objective corneal densitometry (haze) was manually measured over the central 4.0 mm using the Scheimpflug image along 1 meridian on the axis nearest to the maximum K.

Statistical Analysis

Statistical analysis was performed using PASW software (version 18, IBM Inc.). First, a multiple regression analysis was performed to identify significant predictors of CDVA and maximum K 1 year postoperatively. Patients with severe keratoconus, as defined by McMahon et al.,[15] were excluded from analysis because the variability in their outcome measurements was too large for accurate analysis. Postoperative outcomes of maximum K and CDVA were chosen for analysis because they represent the most salient results of CXL

in these disease processes. The topographic maximum K is an objective indicator of disease severity and progression, and the CDVA is the predominant visual function indicator. Preoperative characteristics assessed included patient age and sex, UDVA, CDVA, maximum K, thinnest pachymetry, corneal haze, disease (keratoconus versus ectasia), and topographic cone location. Multiple odds ratio (OR) analyses were performed for characteristics identified as significant on regression analysis.

An improvement in CDVA and maximum K was defined as an increase of more than 2 Snellen lines and flattening of more than 2.0 D, respectively, 1 year postoperatively. Because few patients in the study cohort had a loss of more than 2 Snellen lines of CDVA or a steepening of maximum K of more than 2.0 D, worsening of CDVA and maximum K were defined as a loss of 1 Snellen line or more and a steepening of 1.0 D or more, respectively. This was done to better identify patients who might do poorly with CXL. All patient outcomes that did not meet the above criteria were considered to be stable 1 year after CXL.

RESULTS

One hundred four eyes that had CXL for keratoconus (n = 66) or ectasia (n = 38) were analyzed. Overall, the mean CDVA improved and the mean maximum K flattened from preoperatively to 1 year after CXL; both changes were statistically significant ($P < .001$). Table 1 shows the preoperative and 1-year postoperative CXL measurements.

Corrected Distance Visual Acuity

Multiple Regression Analysis Table 2 shows the individual characteristics assessed and the regression coefficients included in the analysis. In the multivariate regression analysis, the CDVA and maximum K value were the only significant predictors of the 1-year postoperative CDVA.

Odds Ratio Analysis Eyes with a preoperative CDVA of 20/40 or worse were 5.9 times more likely to improve by 2 Snellen lines or more 1 year after CXL (95% confidence interval [CI], 2.2-16.4). Specifically, 22 (43.1%) of 51 eyes with a CDVA of 20/40 or worse improved 2 lines or more compared with 6 (11.3%) of 53 eyes with a preoperative CDVA of better than 20/40. Table 3 shows a complete list of postoperative CDVA OR analyses.

Three eyes (2.9%) lost 2 lines or more of CDVA 1 year after CXL. Table 4 shows the preoperative and postoperative characteristics of these eyes. There was no obvious defining feature of these eyes. However, looking at a 1 line loss of CDVA at 1 year, 8 (15.1%) of 53 eyes with a CDVA better than 20/40 had worsening of 1 Snellen line or more compared with 4 (7.8%) of 51 eyes with a CDVA of 20/40 or worse. However, the difference was not statistically significant (OR, 0.5; 95% CI, 0.14-1.70).

Although the multiple regression analysis identified an association between the preoperative maximum K value and the postoperative CDVA, all OR analyses failed to reach statistical significance.

Maximum Keratometry

Multiple Regression Analysis Table 5 shows the individual characteristics assessed and regression coefficients included in the analysis. In this multivariate regression analysis, preoperative maximum K was the only significant predictor of the 1-year postoperative maximum K.

Odds Ratio Analysis Eyes with a maximum K value of 55.0 D or more were 5.4 times more likely than eyes with a maximum K value of less than 55.0 D to have flattening of 2.0 D or more 1 year after CXL (CI, 2.1-14.0). Specifically, 20 (45.4%) of 44 eyes with a maximum K value of 55.0 D or more flattened by 2.0 D or more compared with 8 (13.3%) of 60 eyes with a preoperative maximum K of less than 55.0 D.

Table 1. Preoperative and 1-year postoperative CXL measurements.

Outcome	Preop	1 Year Postop	*P* Value*
Mean UDVA, logMAR (Snellen)	0.77 (20/118)	0.68 (20/96)	<.001
Mean CDVA, logMAR (Snellen)	0.29 (20/39)	0.19 (20/31)	<.001
Mean maximum K (D)	55.6	54.6	<.001

CDVA = corrected distance visual acuity; UDVA = uncorrected distance visual acuity
*$P < .05$ indicates significant change.

Table 2. Preoperative characteristics included in the multiple regression analysis for the outcome of CDVA.

Preop Variable	Coefficient	Standard Error	*P* Value*
(Constant)	−0.3	0.3	
KC vs EC	−0.02	0.04	.7
Cone location	0.02	0.03	.6
Age	0.003	0.002	.1
Sex	−0.02	0.03	.6
UDVA	−0.003	0.04	.9
CDVA	0.4	0.09	<.001
MRSE	−0.002	0.003	.6
Maximum K	0.007	0.003	.01
Thinnest pachymetry	0.0	0.0	.6
Haze	0.001	0.01	.9

CDVA = corrected distance visual acuity; EC = ectasia; K = keratometry; KC = keratoconus; MRSE = manifest refraction spherical equivalent; UDVA = uncorrected distance visual acuity
*Coefficients were considered significant if $P < .05$.

Table 3. Odds ratios performed at multiple preoperative CDVA stratifications.

Preop CDVA Stratification	Improvement of ≥2 Snellen Lines, n (%)		OR*	95% CI
	In Eyes with Preop CDVA Better than CDVA in Column 1	In Eyes with Preop CDVA Equal to or Worse than CDVA in Column 1		
20/25	0/5	28/99 (28)	1.4x	1.2, 1.6
20/32	0/23	28/81 (35)	1.5x	1.3, 1.8
20/40	6/53 (11)	22/51 (43)	5.9x	2.2, 16.4
20/50	9/72 (13)	19/32 (59)	10.2x	3.8, 27.6
20/63	13/85 (15)	15/19 (79)	20.8x	5.9, 72.6
20/80	20/95 (20)	8/9 (89)	30.0x	3.5, 254.1

CDVA = corrected distance visual acuity; CI = confidence interval; OR = odds ratio
*Relative likelihood that an eye with preoperative CDVA worse than or equal to the preoperative CDVA in the first column will improve by ≥2 Snellen lines compared with an eye with better than the CDVA stratification

Table 6 shows the complete list of postoperative maximum K OR analyses.

Two eyes (1.9%) steepened 2.0 D or more 1 year after CXL. Regarding eyes that continued to have topographic progression at the more subtle 1.0 D level, there was no difference between groups; 4 (10.0%) of 44 eyes with a maximum K value of 55.0 D or more had 1.0 D or more of steepening of the maximum K value 1 year after CXL compared with 5 (8.3%) of 60 eyes with a maximum K value less than 55.0 D. Moreover, eyes with a maximum K value of 55.0 D or more, or less than 55.0 D, were equally likely to remain topographically stable (±1.0 D) 1 year after CXL (OR, 0.9; CI, 0.24-3.40).

DISCUSSION

In our previous studies of 1-year outcomes of corneal collagen crosslinking,[10–12,14,16–18] we found improvements in the mean CDVA, UDVA, maximum K value, quantitative indices of corneal topography, higher-order wavefront aberrations, and subjective visual function after CXL. However, although CXL appears generally promising for eyes with keratoconus and corneal ectasia, from a clinical perspective it would be helpful to identify the characteristics of eyes that do well after the procedure and those that do poorly. This would facilitate proper patient selection and identify possible exclusion criteria. For example, although in our past studies the mean CDVA improved from 20/45 to 20/34, individually 21.1% of eyes improved by more than 2 Snellen lines and 1 eye (1.4%) lost 2 Snellen lines. Similarly, although the mean maximum K value flattened from baseline by a mean of 1.7 D, individually the mean maximum K value flattened by more than 2.0 D in 31.0% of eyes and increased by more than 2.0 D or more in 4.2%.

Table 4. Characteristics of 3 patients who lost 2 or more Snellen lines of CDVA 1 year after CXL.

Characteristic	Patient 1	Patient 2	Patient 3
Eye	Right	Right	Left
Group	KC	EC	EC
Age (y)	22	56	48
Sex	Male	Male	Male
Race	Indian	White	White
Preop CDVA (logMAR)	0.8	0.2	0.3
SE (D)	−9.6	−4.1	−1.0
Maximum K (D)	67.3	43.5	50.9
Thinnest pachymetry (μm)	373	439	420
Haze (densitometry)	15.7	15.7	14.5
Snellen lines lost	2	2	2

CDVA = corrected distance visual acuity; EC = ectasia; K = keratometry; KC = keratoconus; SE = spherical equivalent

Table 5. Preoperative characteristics included in the multiple regression analysis for maximum K.

Preop Variable	Coefficient	Standard Error	*P* Value*
(Constant)	2.0	3.8	
KC vs EC	0.2	0.4	.6
Cone location	0.3	0.2	.2
Age	−0.02	0.01	.2
Sex	−0.7	0.4	.1
UDVA	−0.2	0.6	.8
CDVA	0.1	1.1	.9
Maximum K	0.9	0.03	<.001
Thinnest pachymetry	0.2	0.1	.08
Haze	2.0	3.8	.6

CDVA = corrected distance visual acuity; EC = ectasia; K = keratometry; KC = keratoconus; UDVA = uncorrected distance visual acuity
*Coefficients were considered significant if $P < .05$.

Table 6. Odds ratios performed at multiple preoperative maximum K stratifications.

Preop Maximum K (D) Stratification	Flattening of ≥2.0 D, n (%)			
	In Eyes with Preop Maximum K Flatter Than K in Column 1	In Eyes with Preop Maximum K Equal to or Steeper Than K in Column 1	OR*	95% CI
50.0	1/19 (5)	29/85 (34)	8.4x	1.1, 66.1
55.0	8/60 (13)	20/44 (45)	5.4x	2.1, 14.0
60.0	13/81 (16)	15/23 (65)	9.8x	3.5, 27.8
65.0	19/94 (20)	9/10 (90)	35.5x	4.2, 297.9

CI = confidence interval; K = keratometry; OR = odds ratio
*Relative likelihood that an eye with preoperative maximum K greater than or equal to the preoperative maximum K in the first column will flatten by ≥2.0 D compared with an eye with maximum K flatter than the maximum K stratification

Thus, identifying predictors of these individual good results and bad results would have substantial clinical significance.

As yet, such specific predictors of positive and negative CXL outcomes have not been clearly elucidated. In this effort, 2 studies by Koller et al.[19,20] deserve attention. In the first study of 105 eyes, 3 eyes lost 2 Snellen lines of CDVA at 1 year.[19] Two characteristics—age over 35 years and CDVA better than 20/25—were identified as risk factors for this loss of vision (OR, 13.14 for age and 18.18 for CDVA). Eight eyes (7.6%) showed continued progression of keratoconus 1 year after CXL; progression was defined as an increase in the maximum K value of more than 1.0 D, similar to the definition in our study. Two preoperative characteristics—maximum K over 58.0 D and female sex—were identified as risk factors for continued disease progression (OR, 5.32 for K and 3.11 for sex). In a second study by Koller et al.,[20] a preoperative K value of more than 54.0 D was associated with a greater likelihood of postoperative flattening of more than 1.0 D, a finding corroborated by our study. With regard to clinical decision-making, the latter study conflicts somewhat with the earlier conclusion that a K value of more than 58.0 D was associated with a greater risk for continued disease progression. However, this highlights the importance of defining the clinical goals in an individual CXL patient, as we will discuss shortly.

In our analysis, the only independent predictor of a change in the postoperative CDVA after CXL was the preoperative CDVA. Eyes with worse preoperative CDVA were more likely to have an improvement of 2 Snellen lines or more. Specifically, eyes with a preoperative Snellen visual acuity of 20/40 or worse were 5.9 times more likely to improve by 2 lines or more; 43.1% of eyes with a CDVA of 20/40 or worse had an improvement of 2 lines or more compared with only 11.0% of eyes that had a CDVA of better than 20/40. With regard to eyes that lost vision from the procedure, the most salient indicator of an unwanted outcome, there was no independent preoperative indicator. Of the 3 eyes losing 2 lines or more, there were no consistent causes. When analyzed at the more sensitive endpoint of only 1 line loss, there was a suggestion that eyes with a CDVA of better than 20/40 preoperatively had a greater propensity to lose 1 line (15.1%) than eyes with a worse preoperative CDVA (7.8%). However, this difference was not statistically significant; this could be a result of the small number of eyes that lost vision after the procedure. A larger study might identify good vision as a risk factor, as was found in Koller et al.'s study.[19]

To summarize from the viewpoint of clinical decision-making, from our current knowledge it might be reasonable to conclude that with regard to CDVA, eyes with worse vision initially would expect the greatest chance of actual improvement, all eyes are equally likely to remain stable within 2 lines of CDVA, and eyes with initially good CDVA (better than 20/40) may be somewhat more susceptible to a loss of 1 line.

In our analysis, the only independent predictor of the 1-year postoperative maximum K value was the preoperative maximum K value. Specifically, eyes with a maximum K of 55.0 D or more were 5.4 times more likely to have topographic flattening of 2.0 D or more after CXL than eyes with flatter corneas. However, with regard to eyes in which corneal topography continued to steepen—that is, those in which the crosslinking procedure failed to stabilize the disease—there were no independent predictors of continued topographic steepening even at the more refined level of more than 1.0 D. All eyes were equivalently likely to be stabilized by the CXL procedure. Specifically, in the subgroup with an initial maximum K value of 55.0 D or more, 40 (90%) of 44 eyes had less than 1.0 D of progression 1 year after

CXL. Similarly, in the subgroup with an initial maximum K value of less than 55.0 D, 55 (92%) of 60 eyes were stable.

We will now discuss the implications for patient selection. The essential goal of CXL is to stabilize the progression of ectatic corneal disorders, such as keratoconus and ectasia. Indeed, documented disease progression was an entry criterion in our study. With regard to disease stabilization, CXL indeed appears efficacious; 98.1% of eyes showed less than 2.0 D and 91.6% showed less than 1.0 D of topographic progression over the 1-year follow-up. However, in addition to stabilization of the disease process, this study elucidates other potential benefits of CXL. In particular, the CDVA and maximum K values both improved to a clinically significant extent in a subset of eyes. Twenty-eight (26.9%) of 104 eyes had an improvement in CDVA by 2 Snellen lines or more and 28 (26.9%) of 104 eyes had an improvement in maximum K by 2.0 D or more. Such improvements could aid patients in their spectacle use or contact lens tolerance.

Therefore, knowing the characteristics associated with CXL outcomes and in reviewing previous literature regarding the natural progression of keratoconus and ectasia, we may be able to start selecting eyes for CXL based on preoperative measurements (Figure 1). As shown here, the 2 most important predictors of vision and topography improvement after CXL are preoperative CDVA and maximum K, respectively. Because we found no independent predictors of failure of CXL to stabilize disease progression, it is reasonable that all eyes with progressive keratoconus or corneal ectasia should be considered for CXL treatment with the goal of diminishing disease progression. However, the clinician may still want to take the preoperative CDVA into account before suggesting treatment. Although there were no independent predictors of CDVA loss at the 2 Snellen line or 1 Snellen line level, there was a suggestion that eyes with better than 20/40 CDVA preoperatively had a greater propensity to lose 1 line. Thus, eyes with good visual acuity and progressive disease are generally stabilized (and would likely ultimately lose CDVA as the disease continues to progress without treatment) but may have a somewhat greater chance of losing a line of CDVA as a result of the procedure. The ophthalmologist should be aware of this and the patient properly counseled.

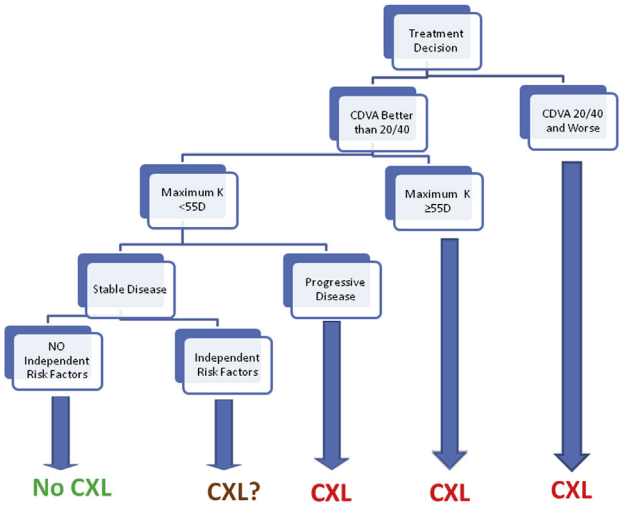

Figure 1. Treatment algorithm for CXL patient selection (CDVA = corrected distance visual acuity; CXL = collagen crosslinking).

Our study did not include eyes with stable keratoconus, which was defined in our protocol as stability over a 2-year period before entry into the clinical trial. However, previous literature suggests that many eyes with ostensibly stable keratoconus are likely to progress slowly over time. Gordon et al.[21] found that all keratoconus eyes with visual acuity worse than 20/40 ultimately were more likely to require penetrating keratoplasty. Furthermore, on average, eyes diagnosed with keratoconus can expect to lose 2 letters of high-contrast CDVA and 4 letters of low-contrast CDVA and have 1.6 D of steepening of the flattest K value over 7 to 8 years.[22,23] Independent predictors of a loss of 10 letters or more (2 lines) of high- or low-contrast CDVA over 7 years were race other than non-Hispanic white, a steeper first definite apical clearance lens, and a CDVA greater than 35 low-contrast letters and 49 high-contrast letters, respectively.[22] In addition, young age, nonwhite racial status, poorer CDVA, and a steeper cornea (flat K) were predictors of 3.0 D or more steepening of the flattest K over an 8-year period. Thus, when taken in light of the published literature on the natural history of keratoconus, our findings may suggest that eyes with worse CDVA, specifically 20/40 or less, and more advanced keratoconus, specifically maximum K of 55.0 D or more, may benefit from CXL despite having "stable" keratoconus. The goal in such cases would not be to diminish disease progression per se but to prevent or postpone keratoplasty by potentially improving spectacle or contact lens tolerance by improving CDVA or diminishing topography irregularity. It is also reasonable for the ophthalmologist to monitor these eyes closely and defer CXL treatment until there is evidence of frank topographic or visual signs of disease progression. Further study is underway to determine the effect of CXL treatment on stable keratoconus and corneal ectasia.

For patients with progressive keratoconus and corneal ectasia, our study shows that eyes with worse CDVA and higher K readings, in general, are more likely to have an improvement after CXL. These findings suggest that all eyes with progressive keratoconus and corneal ectasia should be considered for treatment with CXL with the goal of stabilizing the disease progression. Patients and physicians should be aware of the risk for loss of visual acuity, particularly in eyes with a preoperative CDVA better than 20/40.

WHAT WAS KNOWN

- Previous CXL studies report that in addition to stabilizing the cornea, there is, on average, improvement in topographic and visual acuity outcomes.

WHAT THIS PAPER ADDS

- Eyes with worse preoperative CDVA and higher maximum K values, particularly with a CDVA of 20/40 or worse or a maximum K of 55.0 D or more, were more likely to have improvement after CXL.
- No preoperative characteristics were independently predictive of CXL failure.
- An algorithm is presented to begin to determine patients who are best treated with CXL and those who are poor candidates.

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